Reply to S Riehl and K Pustovoytov (Journal of Archaeological Science 33 (2006) 143-144)

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We appreciate the interest of Simone Riehl and Konstantin Pustovoytov (hereafter R&P) in our publication [10] and here we answer their critical remarks and questions [13]. R&P criticise two aspects: (1) our interpretation of the pollen record from Kutuzhekovo Lake and (2) the information we derived from the St. Petersburg radiocarbon database. We discuss the questions and we show that these do not really affect our earlier conclusions.

1. Interpretation of the pollen record

Fig. 2 of [10] only shows a selection of pollen curves from Kutuzhekovo Lake. The comment by R&P on our interpretation of the vegetation development shows the disadvantage of presenting a selection of pollen curves. Among the pollen taxa which indeed should not have been omitted from the diagram are Chenopodiaceae. For our interpretation of the vegetation history we refer to a more complete pollen diagram of Kutuzhekovo Lake [8]. The botanical nomenclature in this reply is according to [4].

R&P find it difficult to believe that the lower zone (KTH-I) of the pollen diagram from Kutuzhekovo Lake represents a dry steppe or even a semi-desert. They suggest that the relatively high pollen representation of *Betula* sect. Nanae/Fruticosae is not a good argument, because *Betula nana* is an indicator of wet and cool habitats. We stress here that *B. nana* L. and related species with similar ecological requirements, such as *B. exilis* Sukacz, are absent in our study area [1]. The pollen type of *Betula* sect. Nanae/Fruticosae includes some shrub and dwarf shrub birch species from the following environments: mountain shrubs and dwarf-shrubs above the upper tree line (i.e. shrub tundra and sub-alpine shrubs); mountain taiga (*Betula rotundifolia* Spach.); wetlands (*Betula humilis* Schrank) [1]. Kutuzhekovo Lake is situated within an area of ancient sand dunes in an inter-mountain depression. There is no evidence that mires and bogs could have developed on the sandy substrate in the area. Our assumption of dryness is supported by the low organic content (enhanced decomposition during dry phases) of the deposit in the lower part of the core (zone KTH-I). The shrub birch species which nowadays are present in the understory of pine forest may have occurred on the dunes around the lake, when pine forest was absent (values of *Pinus sylvestris* pollen are low in zone KTH-I). Furthermore, the maximum of shrub birch pollen may reflect the mountain shrub belt, when the mountain forest around the depression was significantly reduced. A similar situation is observed in the White Lake pollen record [8] from the more arid inter-mountain depression in adjacent Tuva: *Betula* sect. Nanae/Fruticosae pollen becomes more frequent since ca. 4 kyr BP, while tree pollen values remain low. The climatic significance and ecological status of shrub birch species is a matter of debate. It is probable that mesoxerophytes (*Betula saksarensis* Polozh. et Maltz.), or even psychrophytes (*B. rotundifolia*) are included in the species of the *Betula* sect. Nanae/Fruticosae pollen type, and modern analogues of such vegetation types may not exist. *B. rotundifolia* nowadays occurs in arid mountains under extremely continental climatic conditions (South-Eastern Altai, South-Western Tuva [2,9]).

According to R&P there are no unambiguous xerophytes among the other taxa presented in the Kutuzhekovo diagram. They mention that the genus *Artemisia* is neither indicative of dry steppe, nor of semi-desert. We do not agree with this because in some undisturbed steppe communities, preserved in the Minusinsk depression [1], two xerophytic *Artemisia* species are common: *A. glauca* Pall. and *A. frigida* Willd [1,2]. The former species is co-dominant in the bunchgrass steppe together with *Stipa capillata* and

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Helictotrichon desertorum, the latter species is common in grass steppe with *Festuca pseudovina, Koeleria gracilis* and *Stipa decipiens*. Most *Artemisia* species are high pollen producers [5,7,15]. Studies of pollen in surface samples [6] have shown that plant communities with *Artemisia* dominance produce pollen spectra with more than 40–50% *Artemisia* pollen. The percentages of *Artemisia* pollen in zone KTH-I reach 11–28%, so this pollen should be regarded as mainly transported (i.e. not local) from steppe areas where xerophytes, such as *A. frigida* and *A. glauca*, nowadays are common. The *Artemisia* species mentioned by R&P never dominate in any plant community in the study area [1], so their input into the regional pollen rain should be regarded as negligible. The widespread occurrence of the typical ruderal species (*A. annua* L., *A. jacutica* Drob., *A. scoparia* Waldst. et Kit., *A. sieversiana* Willd.) and the facultative ruderal species *A. vulgaris* L. observed in modern vegetation types [1] could hardly be expected in our fossil record because, according to archaeological evidence [18], the study area was almost completely uninhabited. It should also be noted that the species mentioned as mesophytes (*A. commutata* Bess., *A. dracunculus* L., *A. latifolia* Ledeb.) belong to a mesoxerophytic ecological group and may grow in forest-steppe and meadow-steppe habitats, as well as in 'true' steppe [1,2].

We agree with R&P that *Cannabis* is a typical mesophyte. It is a common ruderal, climatically nonspecific plant in Khakassia. The highest value of *Cannabis* pollen (12%) in the surface sample of the Kutuzhekovo Lake record reflects recent human impact on the environment. But the characteristics of the *Cannabis* curve in the lower part of the diagram are similar to the xerophytic *Artemisia* and Chenopodiaceae. Therefore, we also consider *Cannabis* to be a xerophyte. Nevertheless, the exact ecological status of *Cannabis* in the past remains unclear. Despite its modern preferences, *Cannabis* cannot be definitely regarded as a ruderal taxon for the lower part of the Kutuzhekovo Lake record, for the same reason as with *Artemisia* (see above). There is no reference in the literature concerning natural plant communities with *Cannabis*. However, according to recent observations, *Cannabis ruderalis* grows in mature forest (with *Betula pendula, Populus nigra, Padus racemosa, Ribes hispidulum*) along the Abakan River without traces of anthropogenic disturbance (V.G. Dirksen, unpublished data). *Cannabis* is also present in natural communities in adjacent Tuva (E.A. Volkova, pers. com.). In the case of *Cannabis* pollen in the lower part of the Kutuzhekovo record, the question of its climatic significance indeed remains open.

R&P argue that the proportion of Poaceae in the zone KTH-I is relatively low, but this is not surprising as the pollen grains of Poaceae in steppe areas (common genera *Stipa*, *Festuca*, *Koeleria* and *Helictotrichon* [1]) are generally under-represented [6,12]. This is in contrast with pollen of *Artemisia* and Chenopodiaceae.

R&P point to the absence of Chenopodiaceae as an indication for the absence of open soils. Unfortunately, the pollen curve of Chenopodiaceae was omitted from our simplified diagram [10]. We used the ratio of *Artemisia* and Chenopodiaceae pollen concentrations as an indicator of the moisture level [5,16]. The aridity of zone KTH-I [8] is clearly demonstrated by this ratio.

The most significant features suggesting the onset of wetter conditions at the start of zone KTH-II are the sharp rise of Cyperaceae and the distinct decrease in *Artemisia* and Chenopodiaceae. Juncaginaceae (cf. *Triglochin*) appear at this level and fluctuate together with Cyperaceae. Both taxa reflect wetland development around the lake, starting at the beginning of the zone KTH-II. Moreover, organic-rich sediments were deposited after the KTH-I/KTH-II transition.

The different ecology of two pine species *Pinus sibirica* and *P. sylvestris* [1,2] allows us to explain the different behaviour of their pollen curves. The gradual rise of *P. sylvestris* confirms increased moisture in zone KTH-II, while the low *P. sibirica* values suggest the establishment of cold conditions since ca. 4.3 kyr BP [8]. The replacement of shrub birch by tree birch could reflect the formation of lower mountain forest and forest-steppe within the depression, where the main tree species were *B. pendula* and *P. sylvestris* [1].

It is true that the increase of the human population density after 850 cal BC is not evident in our pollen diagrams. Apparently, the impact on the vegetation by domesticated animals of the nomadic Scythians was not significantly different from the effects of wild herbivore mammals.

2. The interpretation of the radiocarbon database

During the last 200 years archaeologists from institutes in St. Petersburg, Moscow and Novosibirsk have studied the regions of Southern Siberia and Central Asia. In recent years German archaeologists have also participated on projects. The radiocarbon laboratory of the Institute for the History of Material Culture RAS was created in St. Petersburg at the end of the 1950s. The first radiocarbon dates were produced for archaeological sites in Siberia. The organic materials from those sites were often well preserved due to the environmental conditions [20]. Archaeologists who conducted their fieldwork in Siberia, among which were S. Rudenko and M. Gryaznov, used the radiocarbon method as soon as it became available. Radiocarbon dates from the regions under study were also produced by radiocarbon laboratories in Novosibirsk and Berlin.

At the end of 1980s, a computerised database was created at the Institute for the History of Material Culture. This database includes radiocarbon determinations produced by several laboratories. Results based on the database were presented in several publications [17,19]. The radiocarbon records of the database clearly show the chronological gap from the Mesolithic up to the late Bronze Age for the Southern Siberian regions (the Minusinsk and Uyuk depressions). In the radiocarbon record from European Russia, this gap does not exist. There we observe a continuous record of radiocarbon dates from the Mesolithic up to the medieval period. It is important to know if this gap has happened by chance, or if there are specific reasons for it. Not all archaeological sites have been radiocarbon dated, but ^{14}C dates were produced for many sites, in particular for key sites of the different cultures. With the high number of radiocarbon dates in the database we can recognise patterns in the occupation history of the regions. In spite of the long history of archaeological investigations, Mesolithic and Neolithic sites are almost absent here. The first remarkable archaeological culture in the Minusinsk depression is the Neolithic Aphanasievo culture. This is recognisable in the distribution of the radiocarbon dates from the database. The population of this culture was not of local origin and had migrated to the Minusinsk depression from other territories. Bokovenko and Mitev [3] and Vadetskaya [14] discuss the question of the origin of the Aphanasievo culture. Detailed lists of radiocarbon dates for the archaeological cultures located in the Minusinsk and Uyuk depressions, compared with other Eurasian regions were presented in [11] and [18]. In the Uyuk depression, the human occupation history is different from the Minusinsk area, in spite of the proximity. The Aphanasievo population did not reach this region, and only some traces of the Okunevo culture were found during the excavation of the Arzhan-2 monument.

3. Conclusions

Combining all available data, we hypothesised that environmental conditions influenced cultural developments. We concluded that humidity may have been a limiting factor until the end of the Bronze Age. Climate change probably promoted the nomadic economy and intensity of the occupation of the territory [8].

We agree that the peaks of radiocarbon dates in our figs. 3 and 4 are influenced by activities and preferences of individual archaeologists. For the key monuments such as Arzhan-1, a number of radiocarbon dates were produced. By themselves, these dates do not necessarily reflect the intensity of occupation in a region, and cannot show an acceleration in cultural development. Nevertheless, it is clear from the combined archaeological, palaeoenvironmental and radiocarbon evidence that there was a sudden human occupation of a hitherto almost ‘empty’ Tuva. Our conclusion is not based on the radiocarbon data alone, but in the first place on the observed high number of sites from the Scythian period compared to the evidence from the Late Bronze Age. The occupation history of the regions and possible relationships with environmental and climatic changes demand further research which we are developing as an international team.

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